Drilling through the gas hydrae stability down to the deep biosphere

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ABSTRACT

Gas hydrate system on the continental margins has been a matter of debate because its geological behavior has not been understood well. Biologically mediated methanogenic processes are closely related to the occurrence and distribution of gas hydrate deposits, however, little is know about the linkage between gas hydrate and biogenic activities. The processes accumulating/transporting gas and fluid into the gas hydrate stability and potentially seafloor is a key role for the development of gas hydrate system. Understanding of entire gas hydrate system is essential for past/present/future environmental problems because gas hydrate hosts a great volume of methane. Gas hydrate deposit has served as a temporary budget of methane in the gas hydrate stability, however, pressure/temperature change might have destabilized gas hydrate and released methane into the ocean and atmosphere. Methane has considerable green house effect and oxidation potential, resulting in a large environmental impact. Integration of gas hydrate geology with microbiology allows us to establish the behavior of gas hydrate system through the earth's history, it is strongly required that deep gas generation zone is drilled and cored through the shallow gas hydrate accumulation zone. It is also important to predict the behavior of gas hydrate in the future by long-term monitoring of borehole, because ongoing changes caused by gas hydrate deposit can be observed. Observations of the response of gas hydrate to the current temperature/pressure change contribute to the present environmental problems as well.

Gas hydrate system is considered as an envelope of numerical biogeochemical processes in marine sediments. Gas hydrates often contain thermogenic methane generated at greater depth, however, biogenic (bacterial carbonate reduction or bacterial acetate fermentation) methane is also a major component both of shallow and deep gas hydrate deposits. Methane is produced biogeochemically from acetate, a major intermediate of anaerobic methabolism, and H_2/CO_2 as precursors. In sulfate-rich shallow marine environments, methyl and carboxyl groups of acetate produce bicarbonates, these bicarbonates as well as acetate are, however, reduced to methane in the sulfate-depleted deeper sections. These individual reactions are sustained by different consortium of bacteria, reflecting that diversity and development of the consortium contribute to the formation of gas hydrate system. As a result of accumulation of biogenic methane in gas hydrates, they are a major biogeochemical carbon budget in earth surface. Transport of methane into the potential gas hydrate stability is also an important process during gas hydrate accumulation. Fluids migrate preferentially in permeable layers such as thrust/fault, fracture zone, and sandy bed; these layers play a role of input/output path of energy and habitat for bacteria. Additionally, gas hydrate deposits host a large amount of fresh water composing hydrate crystals as well as enclosed methane. Massive dissociation of gas hydrate in response to pressure/temperature changes may emit a great deal of reduced carbon (methane) and fresh water into sediment-seawater column, leading to a significant affects on the marine biosphere.

Drilling/coring through gas hydrate interval has been, therefore, one of the most important topics during ODP and IODP researches. Here we propose an expedition more focused on gas hydrate systematics including biogeochemical processes such as generation, transport, accumulation, and subsequent release of methane in marine environment. Recent developments of drilling/coring techniques have allowed the investigation down to the deeper methanogenic zone underlying the gas hydrate stability and the operation in high methane flux area, where high bacterial activities have occurred through the sediment column. Western margin of the Pacific Ocean is feasible for this focused research, because of the occurrence of gas hydrate with a number of methane activities in different geological settings (Fig. 1). Velocity amplitude anomaly (VAMP), blanking, and gas chimney on seismic images, and giant gas plumes from the seafloor and mud volcano/pock mark as well as the widespread distribution of BSRs are indicative of high methane production and flux and are often observed in this region. Drilling through these gas-rich structures down to deep methanogenic interval may characterize the processes and quantify the bacterial activities contributing to the gas hydrae accumulation and related methane activities.

In addition, long-term monitoring of flux and variation of gas and pore fluid geochemistry in the borehole and on the seafloor is a proxy of bacterial activities and fluid migration associated with gas hydrate accumulation, which is useful to evaluate ongoing methanogenic processes and behavior of gas hydrate system in response to environmental changes. These time-series data will resolve the essential questions; where and how much do the bacterial activities and fluid migration currently occur at depth, and how do these phenomena change in the future?

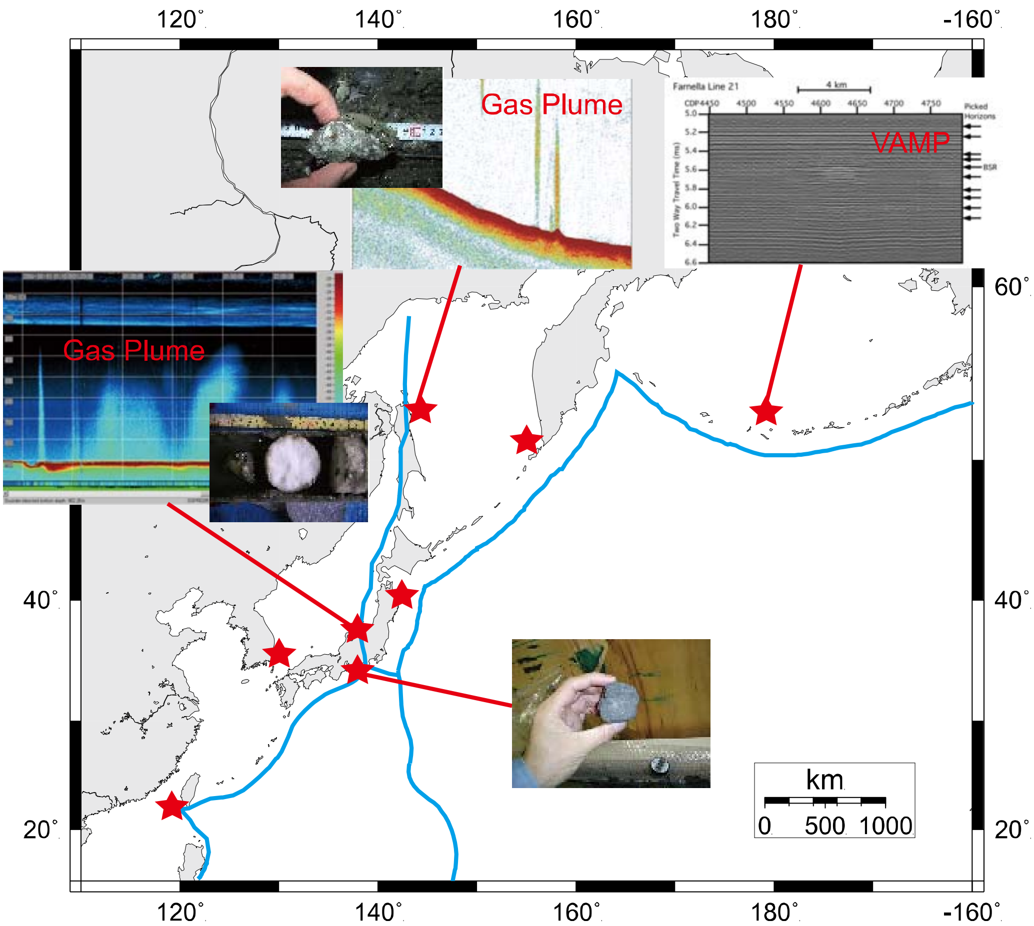

Fig. 1: Western margin of the Pacific Ocean. Stars represent locations where gas hydrates were collected or gas hydrate-related phenomena were observed.